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other interested bodies, but of these, nine have subsequently been abandoned. At least five patents have been developed to such a stage as to be ready for immediate industrial application.

It will be obvious from this short summary of the activities of the department, based upon information kindly supplied to me by Sir Francis Ogilvie, that this great scheme of state-aided research has been conceived and is administered on broad and liberal lines. A considerable number of valuable reports from its various boards and committees have already been published, and others are in the press, but it is, of course, much too soon to appreciate the full effects of their operations. But it can hardly be doubted that they are bound to exercise a profound influence upon industries which ultimately depend upon discovery and invention. The establishment of the department marks an epoch in our history. No such comprehensive organization for the application of science to national needs has ever been created by any other state. We may say we owe it directly to the Great War. Even from the evil of that great catastrophe there is some soul of goodness would we observingly distil it out.

T. EDWARD THORPE

(*To be concluded*)

### LIFE IN OTHER WORLDS

Does life—especially intelligent life—exist elsewhere than on the earth? Three letters in recent numbers of *SCIENCE* discuss this age-old problem. And it is noticeable that, as usual, the astronomers take the affirmative and the biologists the negative side of the argument. There may be two reasons for this.

1. Astronomers, physicists, mathematicians, are accustomed to hold a more receptive attitude, an open mind, toward hypotheses that can not be definitely disproved. This frame of mind is natural and adapted to their work. They are accustomed to deal with problems which can be solved by mathematical and deductive methods. A limited number of solutions appear, all of them to be receptively considered until they can be definitely disproved.

The biologist, on the other hand, deals with a different sort of problem. His evidence is almost always inductive, experimental. His subjects are far too complex, too little understood, to admit of mathematical analysis, save in their simpler aspects. And always he is compelled to adopt toward the illimitable numbers of possible explanations, a decidedly exclusive attitude, and to leave out of consideration all factors that have not something in the way of positive evidence for their existence. If he fails to do so, he soon finds himself struggling hopelessly in a bog of unprofitable speculations. A critical rather than a receptive frame of mind is the fundamental condition of progress in his work.

2. The second reason is that the astronomer or cosmologist has in mind when he thinks of this problem, the physical and chemical conditions that would render life possible. If these be duplicated elsewhere he sees life as possible, and by the incidence of the laws of chance probable or almost certain, if they be duplicated often enough. Viewing the innumerable multitude of stars, each of them a solar system with possible or probable planets analogous to our own, he sees such multitudinous duplications of the physical conditions that have made life possible on our earth, that it appears to him incredible that all stand empty and lifeless.

The biologist, on the other hand, has at the forefront of his mind the history and evolution of life on the earth. He knows that although these conditions favoring the creation of living matter have existed on earth for many millions or hundreds of millions of years, yet life has not come into existence on earth save once, or at most half a dozen times, during that time. The living beings on earth are reducible at most to a few and probably to one primary stock, all their present variety being the result of the evolutionary processes of differentiation and adaptation. It must appear therefore to him that the real conditions for the creation of life on earth have involved, not merely the favoring physical conditions, but some immensely complex concatenation of circumstances so rare that even

on earth it has occurred probably but once during the æons of geologic time. The marvelous complexity of the fundamental substance of life, so complex even in its simplest forms that his most precise and elaborate methods of analysis give him but a partial and tentative comprehension of its real structure, must needs strengthen his concept of the immense complexity of the conditions necessary to its creation and evolution. If these conditions have not been duplicated on earth during the whole of the recorded history of life from the Cambrian down to the present day, it appears to him infinitely less probable that they have been duplicated elsewhere than on the earth.

That the "man in the street" should be sympathetic with the astronomer's rather than the biologist's conclusion is natural enough. The physical probabilities are obvious enough to all; the complexity of life and its conditions he does not realize; nor does he sense the minute relative proportion of time during which intelligent life has existed upon earth, or the vast and impassable barriers of space that preclude the transfer of organized matter from star to star. Moreover, to admit the probability of extra-mundane life opens the way for all sorts of fascinating speculation in which a man of imaginative temperament may revel free from the checks and barriers of earthly realities.

Such life, if it exists, would surely be evolved *ab initio* on independent lines of adaptation and the probabilities would be overwhelming that the results of the æons of its evolution, if by some rare chance it developed intelligent life simultaneously with its appearance on the earth, would be a physical and intellectual type so different fundamentally from our own as to be altogether incomprehensible to us even if we recognized it as being intelligence or life at all. Who that has studied the ant or the bee has failed to be impressed with the unplumbed mysteries in its sensations, its psychology, its inner life! We are far from any full understanding of the intelligence, if I may use the word, of the social insects, relatives, albeit distant rela-

tives, of our own, brought up under the identical environment of terrestrial conditions. How much farther would we be from any comprehension of the intellectual processes of a race of beings whose ultimate origin was wholly different from ours, whose evolution was shaped under conditions that, however closely parallel, could not have been identical with those of the earth. Indeed, if we are to take a receptive attitude in this matter, why limit ourselves to protoplasm as the basis of life? What reason have we to suppose that a self-perpetuating substance, capable of acquiring the heterogeneity of function, the multiple complexity of structural adaptation, the specialization of parts, the elaboration of control and correlation organs, and finally the dominance of these last and development of conscious and intelligent beings, must necessarily be based upon the semi-liquid jelly upon which life, as we know it, is fundamentally based? Other substances, solid, liquid, or even gaseous, may have similar capacities, may have carried them out under different conditioning laws, to a result equally complex and marvelous. We know of nothing of the sort. But would we know of it if it existed, even if it existed upon earth? Would there be any conceivable method of communication, any common ideas, interests, or activities, between such beings and ourselves? It does not appear probable. How much less the probability of communication across the void of interplanetary space.

To suppose that parallel evolution could go so far as to produce similar methods of exploiting the earth to those used by civilized man—irrigation canals, cities, or other such phenomena of the immediate present—in life evolved independently in different planets—and to produce them at an identical moment in geologic time—would seem to be the result of those limitations of constructive or creative thought which are characteristic of myth and fairy-tale, of the anthropomorphic god, or the animal that thinks and talks like a man. Civilized men cannot form any real concept of intelligent life on Mars save in terms of civilized life on earth. Yet, so far as we may judge

from earth conditions, if life exists at all on Mars, it is a thousand to one that it is not intelligent life, for intelligent life on earth is a phenomenon that has existed for about a thousandth part of the geologic record of life. And it is a hundred thousand to one that it is not civilized life, for civilized life has existed at the utmost for a hundredth part of the time that man as such has been on the earth. Could we view the earth from without at any earlier portion of her history, we would by no means conclude that the existence of life must needs involve or culminate in the existence of intelligent life, still less of civilization. We have no means of knowing whether its existence at the present moment is a transitory episode or the commencement of a new era. But if it be the latter, it is probable that the external evidences of civilization a hundred centuries in the future would be as incomprehensible to us to-day, as impossible to interpret in the light of our present knowledge and customs, as our modern civilization would be to the *pithecanthropos* or the chimpanzee. Does any one seriously suppose, after considering the trends and progress of the last few centuries, that our descendants a thousand centuries hence will still be growing grain and irrigating fields for human provender? Such primitive expedients in food production will probably be obsolete in a hundredth part of that time. Life on earth at any other moment than the immediate present would not be indicated to an outsider by any such evidence as our present civilization might afford. Nor is it in the least probable that life upon another planet would be indicated by such evidence at any stage of its existence, or would have any resemblance to our own sufficient for us to recognize it.

In sum it appears to me as a paleontologist that

1. The complex concatenation of circumstances necessary to bring about the initiation of life has occurred upon earth half a dozen times at most, probably but once, in an environment that has apparently been favorable for a thousand million years. The probability of its occurring in a substantially similar

environment upon another planet is so slight as to be practically reducible to a mathematical zero in any particular instance.

2. The number of solar systems being almost infinite, we might regard the number of such possible favorable environments as amounting practically to infinity.

3. The resultant of these two considerations is that there is a finite and reasonable chance that life has existed or will exist somewhere else in the universe than on this earth alone.

4. The probability that intelligent life exists is vastly less, and that anything in the least analogous to our civilization exists at the present time is so slight as to be negligible.

5. If any life involving the development of self-consciousness, of abstract thought and introspection analogous to the higher intelligence of mankind, or the control of environment and utilization of natural resources that we call civilization, should develop independently upon some other planet out of the preexisting simpler phases of life, it probably—almost surely—would be so remote in its fundamental character and its external manifestations from our own, that we could not interpret or comprehend the external indications of its existence, nor even probably observe or recognize them.

6. In any specific instance, such as other planets of our own system, the probabilities of the existence of any kind of life amount to practically zero. The probabilities of an intelligent life upon Mars or Venus or elsewhere in our system so similar to our own in its character and manifestations as to be indicated by irrigation canals, cities, or other manifestations of human civilization, appears to be zero of the second degree. The most that one can allow as a reasonable possibility is that there may be some form of life existing somewhere else in the universe than upon our planet. That we have or shall ever get evidence of its existence appears to me practically impossible in the light of present knowledge and limitations.

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